

ICELAND AS A MODEL FOR CHEMICAL ALTERATION ON MARS. J. L. Bishop¹, P. Schiffman², E. Murad³ and R. Southard⁴, ¹SETI Institute/NASA-ARC, MS 239-4, Moffett Field, CA 94035 (jbishop@mail.arc.nasa.gov), ²Dept. of Geology, UC Davis, Davis, CA, 95616, ³Bavarian Geol. Survey, Leopoldstrasse 30, Postfach 389, 95603 Marktredwitz, Germany, ⁴Dept. of Land, Air & Water Resources, UC Davis, Davis, CA, 95616.

Abstract: Subglacial volcanic activity on Iceland has led to the formation of a variety of silicate and iron oxide-rich alteration products that may serve as a model for chemical alteration on Mars. Multiple palagonitic tuffs, altered pillow lavas, hydrothermal springs and alteration at glacial run-off streams were observed during a recent field trip in Iceland. Formation of alteration products and ferrihydrite in similar environments on Mars may have contributed to the ferric oxide-rich surface material there. The spectral and chemical properties of Icelandic alteration products and ferrihydrites are presented here.

Introduction: The surface mineralogy on Mars holds information about the climatic and geochemical record that may provide clues to when water was present. The rock compositions are basaltic to andesitic [1, 2] and many of the rocks near the Pathfinder lander contain surface coatings [1]. The soils contain elevated Fe and S levels compared to the rocks [3] and definitive identification of specific minerals has been difficult because of the poorly-crystalline phases in the soils. The alteration processes that control which silicate and iron oxides/oxyhydroxide (FeOx) minerals form are directly linked to environmental conditions and physical factors on Mars. Spectroscopic analyses of terrestrial soils and alteration products with known weathering histories and formation conditions are essential for interpretation of the martian spectra.

Altered Basaltic Material: Palagonitic tuff samples and portions of altered pillow lava were collected from a volcanic tuya and ridge in western Iceland for a recent study [4]. Geochemical and mineralogical analyses have been performed on Icelandic samples formed via palagonitization and surface alteration in order to characterize the similarities and differences among the alteration products in these samples. The primary focus in this study is on the $<2\ \mu\text{m}$ particles of the alteration products. These cluster into larger aggregates which were dry sieved into <45 and $>125\ \mu\text{m}$ groups. Reflectance spectra of these samples are shown in Figs. 1-3. The palagonitic tuff contains more clay minerals and has a higher Al/Fe ratio than the altered pillow. The altered pillow lava contains higher amounts of nanophase (np) FeOx. The visible spectra of the $<2\ \mu\text{m}$ fractions of both Icelandic samples are similar to bright Martian soils measured by Pathfinder. The coarser aggregates of the $<2\ \mu\text{m}$ alteration products have darker visible/near-IR spectra and may have implications for duricrust on Mars.

Figure 1. Reflectance spectra from 0.3 to $3.2\ \mu\text{m}$ of the Icelandic tuff and altered pillow lava samples (from [4]).

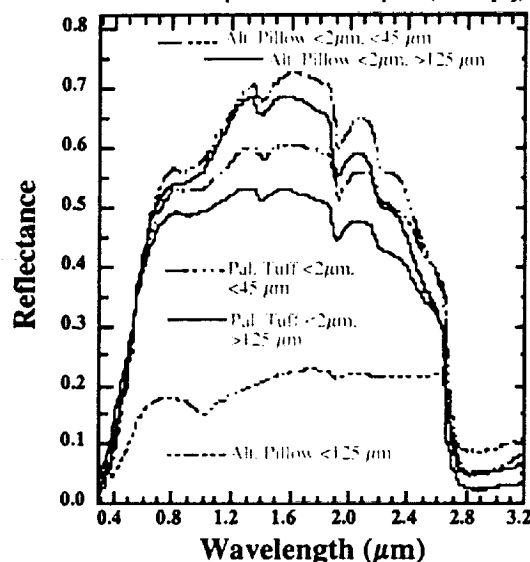


Figure 2. Reflectance spectra from 2000 to $400\ \text{cm}^{-1}$ of the Icelandic tuff and altered pillow lava samples (from [4]).

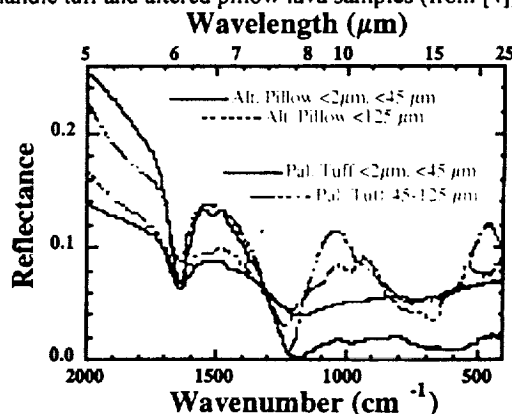
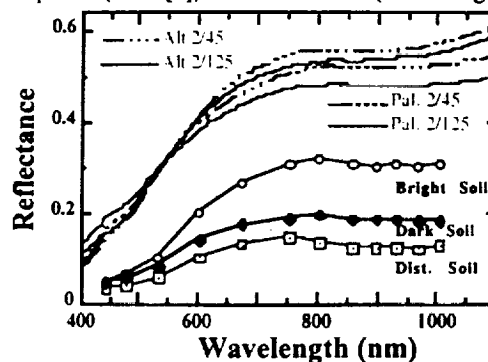
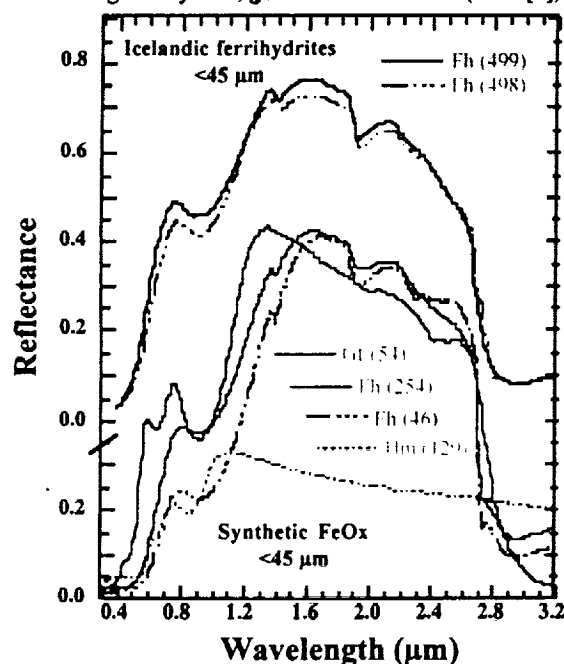


Figure 3. Spectra from 400 to 1100 nm of the pal. tuff and altered pillow (from [4]) and of Mars soil (from Yingst [5]).



Ferrihydrite: Ferrihydrite samples were collected from a thermal spring and a cold stream in the Landmannalaugar region of Iceland. Chemical and spectroscopic analyses have been performed in a recent study [6] on the air dried and fine-grained fractions of these samples. The ferrihydrite from the cold stream is a nearly pure sample, containing small amounts of Si, Ca and P. The ferrihydrite from the thermal pool is a less pure sample, containing larger amounts of amorphous Si and P. The XRD and spectral features for this sample are also consistent with a less crystalline structure. The spectral character of these Icelandic ferrihydrites are compared with those of synthetic ferrihydrites and other FeOx minerals in Figs. 4 and 5.

Figure 4. Reflectance spectra from 0.3 to 3.2 μm of the Icelandic ferrihydrites (498, 499) and synthetic FeOx minerals including ferrihydrite, goethite and hematite (from [6]).

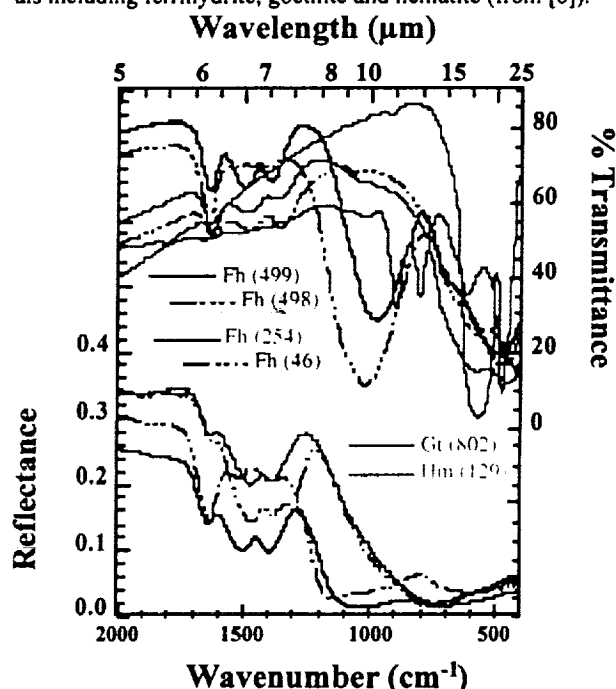


Ferrihydrite is characterized by a broad Fe^{3+} excitation band near 0.92 μm and a strong Fe-O absorption band near 475 cm^{-1} ($\sim 21 \mu\text{m}$) in transmittance spectra and near 680 cm^{-1} ($\sim 14.7 \mu\text{m}$) in reflectance spectra. Multiple bands due to H_2O and OH are also present for ferrihydrite. Natural ferrihydrites frequently exhibit a band near 950-1050 cm^{-1} ($\sim 10 \mu\text{m}$) that is typically not observed for synthetic ferrihydrites and is attributed to Si in the structure. An additional doublet at ~ 1400 and 1500 cm^{-1} ($\sim 7 \mu\text{m}$) is characteristic of pure ferrihydrite from natural and synthetic sources.

Aqueous processes on Mars: Direct evidence of liquid water on Mars has not been found; however, runoff and outflow channels in Viking images were thought to have been formed by water [7] and led to climatic models describing a warm and wet early Mars

[8]. The exciting discoveries of possible oceans [9], water seepage [10, 11], sedimentary layers [12], and a gray hematite deposit [13] on Mars support earlier suggestions of aqueous processes [14] and open many new questions about surface water and the possibility of chemical alteration on Mars. Ferrihydrite formed in thermal springs or cold run-off streams in volcanic environments at an earlier time on Mars could be contributing to the fine-grained FeOx present in the current dessicating climate. Altered volcanic material formed in large-scale palagonitic tuffs or via surface alteration of ash, tephra or lava could be contributing to the 1-2 μm sized dust particles on Mars.

Figure 5. Reflectance spectra from 2000 to 400 cm^{-1} of the Icelandic ferrihydrites (498, 499) and synthetic FeOx minerals including ferrihydrite, goethite and hematite (from [6]).



References: [1] McSweeney H. et al., (1999) *JGR*, 104, 8679-8715. [2] Christensen P. et al. (2000) *JGR*, 105, 9623-9642. [3] Bell J. et al. (2000) *JGR*, 105, 1721-1755. [4] Bishop J., P. Schiffman, & R. Southard (2001) *Geol. Soc. London*, sub. [5] Yingst R. A. et al. (2000) *5th Intl. Mars Conf.* # 6199. [6] Bishop J. & E. Murad (2001) *Geol. Soc. London*, sub. [7] Carr M. (1981) *The Surface of Mars*. [8] Pollack J. et al. (1987) *Icarus*, 71, 203-224. [9] Head J. et al. (1999) *Science*, 286, 2134-2137. [10] Malin M. and K. Edgett (2000) *Science*, 288, 2330-2335. [11] Carr and Malin [12] Malin M. and K. Edgett (2000) *Science*, 290, 1927-1937. [13] Christensen P. et al. (2000) *JGR*, 105, 9623-9642. [14] Baker V. et al. (1991) *Nature*, 352, 589-594.

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